

**Introduction:**

In this study, we meticulously analyze individuals' subtleties of cognitive deterioration at several time points. We compare the changes between groups of people with and without dementia using a mixed-effects ANOVA approach. This method, known for its robustness, allows us to comprehend the typical course of cognitive aging and the variations between and among individuals throughout time. By incorporating both within-subject (time or visits) and between-subject (dementia status) aspects, our overarching goal is to clarify the intricate dynamics of cognitive decline and pinpoint potential factors that may contribute to its heterogeneity, thereby advancing our understanding of cognitive aging and dementia.

**Research Question 1:** How do MMSE scores differ over time between demented and nondemented individuals, and is the rate of change different between the two groups?

**Research Question 2:** Do MMSE scores change over time in a gender-dependent manner in individuals, and how does gender affect the trajectory of cognitive change as measured by MMSE?

**Data cleaning and preparation:**

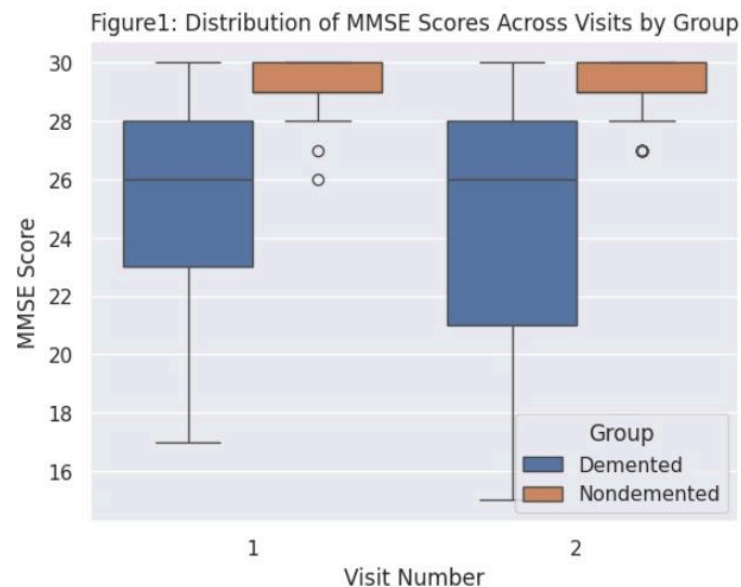
In this research, not all variables are helpful for my experimental questions so I will keep only the following columns: Group, Visit, MMSE, and Subject ID. Among them, I found some nulls in MMSE, and I chose to delete rows with nulls to ensure the accuracy of the results. This meticulous data-cleaning process ensures the validity of our findings.

Meanwhile, there are three types in Group. There are three types of Groups: Nondemented, Demented, and converted; we are not interested in converted data. We are mainly interested in Nondemented vs Demented, so I deleted the group's converted rows. As I delved deeper into the dataset, I realized that to facilitate our MIXED ANOVA STUDY, the VISIT and GROUP data types should have been modified to CATEGORICAL TYPE. Therefore, I modified the data types in the initial process.

**Exploratory Data Analysis:**

In Figure 1, the box plots clearly and concisely represent the distribution of MMSE scores divided into demented and non-demented groups at two different visits. From the first to the second visit, the median score for the dementia group (decreased from nearly 26 to about 21, indicating a general decline in cognitive functioning over time in the dementia group. Also, the IQR was narrower at the first visit, suggesting a more centralized MMSE score. And by the second visit, the IQR was wider, indicating that the distribution of scores became more spread out. The outliers in the dementia group (dots in the figure) also reflect that individual participants had significantly different cognitive levels than other group members. In contrast, the median MMSE score for the non-dementia group remained around 29 across the two visits, with no significant change in box length, suggesting more stable cognitive functioning. No outliers were observed in this group, further confirming the consistency of the score distribution within the non-dementia group. For further research, we can examine

factors like age, sex, education level, and socioeconomic status in influencing cognitive outcomes.



## Exploratory data analysis:

### Research question 1

This figure illustrates a comparative trend in MMSE scores across two separate visits for individuals classified into demented and nondemented groups. We found that those in the demented group exhibited a decline in scores over time, signaling a deterioration in cognitive functions. In contrast, the nondemented group maintains a consistent score level between visits 1 and 2, which shows no significant change in mental status within the studied interval. Meanwhile, the demented group shows variability in scores during the second visit, as indicated by the longer error bars, which could reflect a broad range of cognitive trajectories within the group. The consistently higher scores in the nondemented group serve as a baseline for normal cognitive aging, underscoring the impact of dementia on cognitive decline.

In Table 1, we perform a mixed-design ANOVA on the MMSE scores at two visits, considering the dementia status (Group) and visit time (Visit). The group effect shows a significant and statistically significant difference in cognitive scores between the demented and nondemented groups, with an F-value of 101.443, a p-value less than 0.001, and a large effect size of 0.44, suggesting that dementia is associated with substantial variance in cognitive performance. Time has a substantial impact on cognitive scores as well, as demonstrated by the visit number, with an F-value of 6.125 and a p-value of 0.015. However, the effect size is 0.045, indicating a more gradual development. Notably, the interaction between the group and visit suggests that the demented and non-demented groups' trajectories of cognitive progress differ, as evidenced by an F-value of 5.123, a p-value of 0.025, and an effect size of 0.038. These findings provide a detailed picture of how cognitive function may decrease in a clinical setting by highlighting the crucial interaction between dementia status and time in understanding cognitive decline.

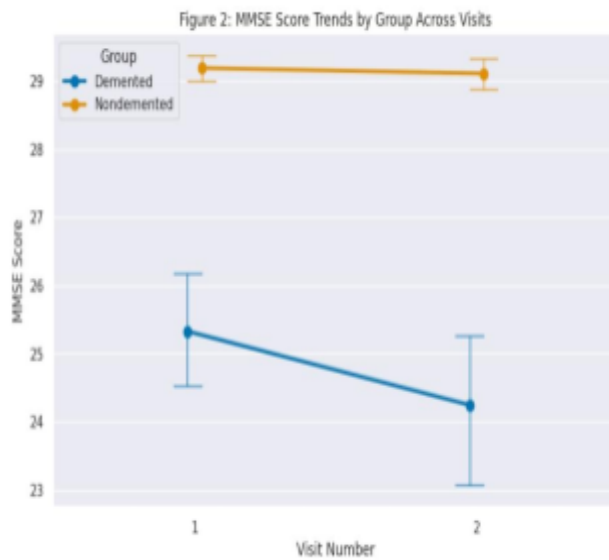


Table 1

	SS	DF1	DF2	MS	F	p-unc	np2	eps
Source								
Group	1273.878	1	129	1273.878	101.443	0.000	0.440	nan
Visit	15.634	1	129	15.634	6.125	0.015	0.045	1.0
Interaction	13.078	1	129	13.078	5.123	0.025	0.038	nan

- Tauchly's test of sphericity = 1: This means that the assumption of sphericity is not violated
- Test of normality(Visit 1:  $W = 0.806517$ ,  $p < 0.001$ ; Visit 2:  $W = 0.760253$ ,  $p < 0.001$ ): The data deviates significantly from the normal distribution
- Homogeneity of variances: The Levene test has a W-statistic of 1.588602 and a p-value of 0.208635, higher than the usual significance level of 0.05. This means that we cannot reject the null hypothesis of variance alignment

## Research question 2

In this mixed ANOVA, we analyzed the effects of time and gender on Mini-Mental State Examination (MMSE) scores, a tool for assessing cognitive function. The analysis found that participants showed a statistically significant decrease in MMSE scores over time, specifically, an average reduction of 0.645 points between visits. However, gender did not show the same statistical significance as an influencing factor; although men's scores were, on average, 1.345 points lower than women's scores, the p-value for this difference was 0.025, which does not reach the conventional level of statistical significance. In addition, the interaction of time and gender did not significantly affect the change in MMSE scores, with a coefficient on the interaction of 0.347 and a p-value of 0.391. These results reveal a trend in cognitive functioning over time and point out that gender was not the primary driver of this change in the current sample. This suggests that further research is needed to explore how and under what conditions gender influences cognitive decline.

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- Test of normality: The data deviates significantly from the normal distribution

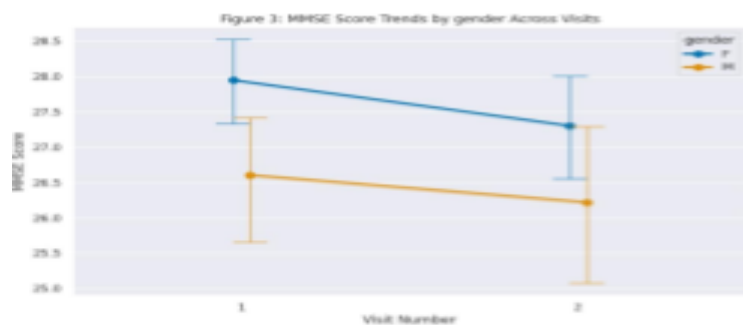
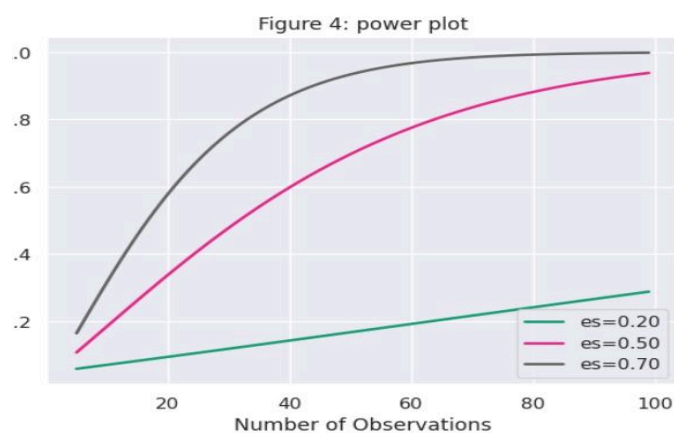


Table 2

Term	Coefficient	Std. Err	z	P> z	CI 95%	Row
Intercept	27.949	0.391	71.546	0.000	[27.183, 28.714]	
C(Visit)(T.2)	-0.645	0.263	-2.455	0.014	[-1.160, -0.130]	
C(gender)(T.M)	-1.345	0.598	-2.249	0.025	[-2.518, -0.173]	
C(Visit)(T.2):C(gender)(T.M)	0.347	0.405	0.858	0.391	[-0.447, 1.141]	

## Statistical power analysis:

For a theoretical experiment with power = 0.91, alpha = 0.05, and effect size = 0.7, we can get the proper sample size 46 using statistical power analysis. The figure 4 shows a power plot for statistical tests with different effect sizes: 0.20, 0.50, and 0.70. The x-axis represents the number of observations, and the y-axis represents the power, the probability of detecting an effect if it exists. For minor effects (es=0.20), even 100 observations don't achieve 80% power. For medium (es=0.50) and significant effects (es=0.70), power reaches 80% at sample sizes between 40 to 60 and just under 40, respectively. The plot helps determine how many observations are needed to detect effects of various sizes.



## Conclusion:

In our research, we found out that dementia status and duration significantly affect MMSE score performance, and the pattern of cognitive change during follow-up is significantly different between demented and non-demented individuals. Meanwhile, gender was not the primary driver of this change in the MMSE score.

